

COASTAL ZONE
INFORMATION CENTER

BARRIER ISLAND PROCESSES

BY

STEPHEN B. BENTON

HEAD, TECHNICAL SERVICES

NORTH CAROLINA DEPARTMENT OF
NATURAL RESOURCES
AND
COMMUNITY DEVELOPMENT

OFFICE OF COASTAL MANAGEMENT

September 30, 1981

GB
475
.N8
B46
1981

GB475.N8B46 1981

BARRIER ISLAND PROCESSES

Barrier Islands

Barrier islands such as North Carolina's Outer Banks and other beaches are a product of wind, wave, and current energy along the ocean, land interface. They are found world wide along continental margins characterized by low tectonic or mountain building activity, and broad, gently sloping Coastal Plains. Physically, they consist of a pile of loose unconsolidated sand and shell resting on the sediment layers which make up the Coastal Plain and continental shelf. Except where large dunes have developed, such as Jockey's Ridge, North Carolina's barrier islands are typically 40 feet or less thick. They range from approximately 1/4 to 4 miles in width and are generally separated from the mainland by sounds, lagoons, rivers, or marsh systems. Barrier island systems are broken into individual island segments by inlets. The inlets allow a tidal exchange of water between the ocean and sounds or lagoons and provide an outlet for river discharge.

There is considerable variation in the size and shape of barrier islands. This is a function of differences in the amount of sediment available for their formation, island orientation with respect to prevailing winds, wave and storm climate, the presence or absence of topographic relief on the coastal plain sediment surface (relict barrier islands) and a host of other conditions and variables.

Barrier islands in North Carolina can, however, be grouped into three basic types; simple, complex and compound (Figure 1). A simple barrier island consists of the following minimum elements or zones which, from ocean to estuary include; the nearshore or littoral zone, berm, frontal dune system, back dune flat and marsh or tidal flat zone. Complex barrier islands generally have the same elements with the addition of a back barrier dune complex. This generally reflects a surplus in the sediment supply necessary for basic barrier island maintenance.

Compound barrier islands consist of the elements of a simple or complex barrier island developed against and on a remnant of a relict barrier which was produced several thousands of years in the past. These are best known from the Georgia Sea Islands though Kitty Hawk Woods, Collington Island and the Ocracoke Village portion of Ocracoke Island have been proposed to be remnants of a relict barrier island.

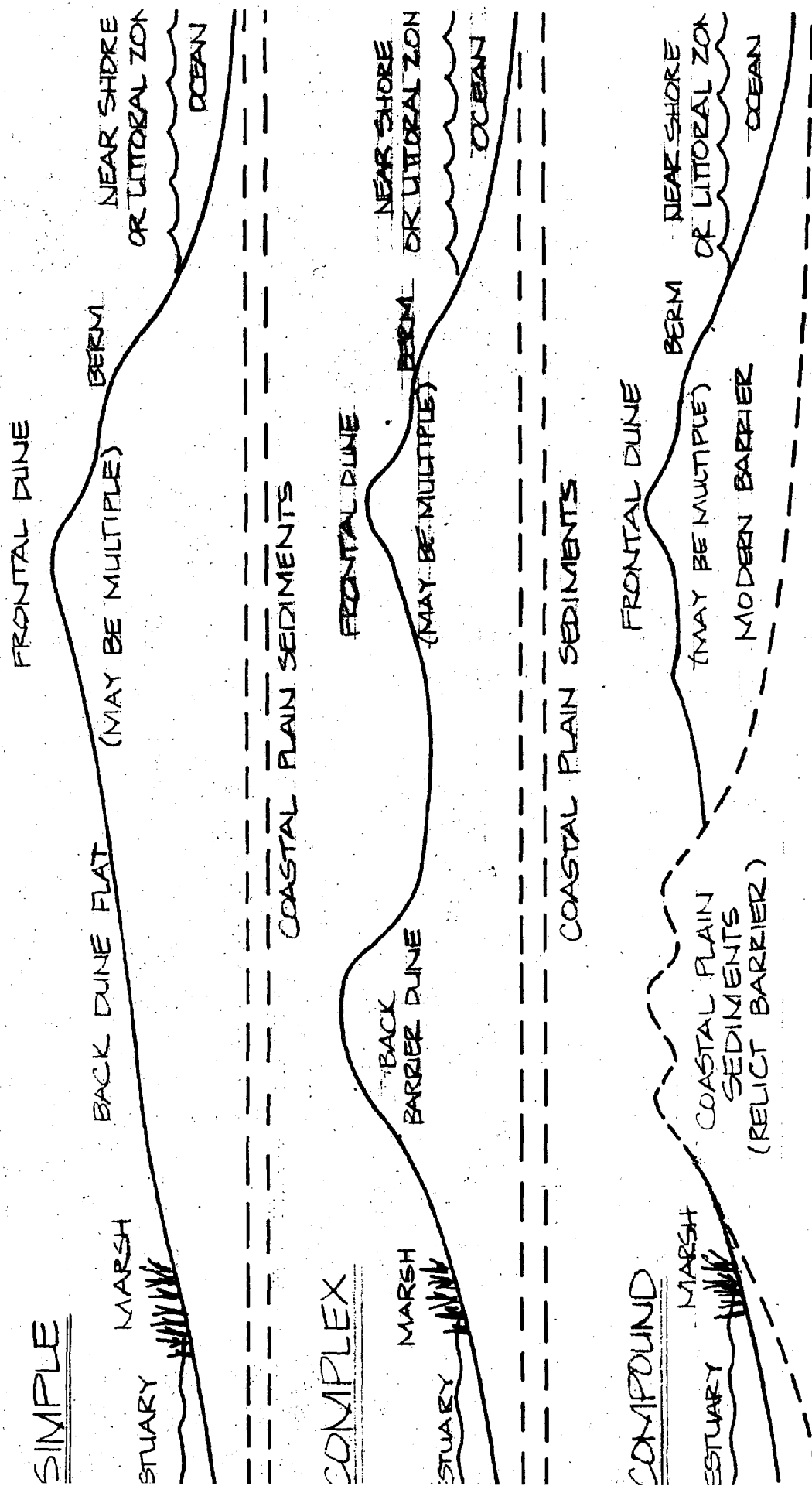
Sea Level Fluctuations

For the past two million years, the coastal areas of the world have been subject to relatively rapid (in a geological sense) changes in sea level. These changes have been brought about by the alternate lock up and release of water from the ocean basins by the continental ice sheets of the "ice ages" or Pleistocene. During this time, at least four major glacial events have occurred which resulted in a lowering of sea level by as much as 400 feet below its present level. When these ice sheets melted, sea level rose to as high as 200 feet above its present level.

The last of the major glacial events ended 18,000 years ago and sea level has risen to its present level since that time, a process that is continuing today. Most recent studies indicate that the current rate of sea level rise is approximately one foot per century.

US Department of Commerce
NOAA Coastal Services Center Library
2234 South Hobson Avenue
Charleston, SC 29405-2413

FIGURE 1.
TYPICAL BARRIER ISLAND PROFILES



Shoreline Change and Sea Level Rise

As sea level has risen and fallen, the location of the shoreline has migrated back and forth across the Coastal Plain and Continental Shelf. Since sea level is presently rising, the shoreline is migrating westward resulting in shoreline recession or erosion. Though the current sea level rise of one foot per century doesn't sound very significant, the horizontal translation on the low slope of the Coastal Plain ranges from 100 to 1000 times the vertical change (Figure 2). In northeastern North Carolina, one must travel inland as far as 75 miles to reach an elevation of 25 feet above sea level. A large portion of mainland Dare and Hyde County is less than five feet above sea level.

Long Term Shoreline Change Rates In North Carolina

Long term shoreline change or beach erosion varies considerably along the North Carolina coast. Generally, the north-south trending coastal segments erode faster than east-west trending segments. Both erode faster in the vicinity of inlets. Some portions of the shoreline are accreting or building seaward. Of these, some appear to be relatively short term or temporary phenomena while others (the areas forming the western arm of the three capes) have a net accretion which has been going on for up to 4,000 years.

Erosion rates range generally from 2 to 6 feet per year over the long term. Near inlets, the erosion may range up to 25 feet per year. This is not to say that a given stretch of beach with an erosion rate of 6 feet per year will erode 6 feet every year. Erosion generally occurs in jumps of perhaps 10 to 50 feet as a result of large storms which only occur once in 2 to 5 years or more. Near inlets, however, the erosion may be more regular and even occur when there are no storms.

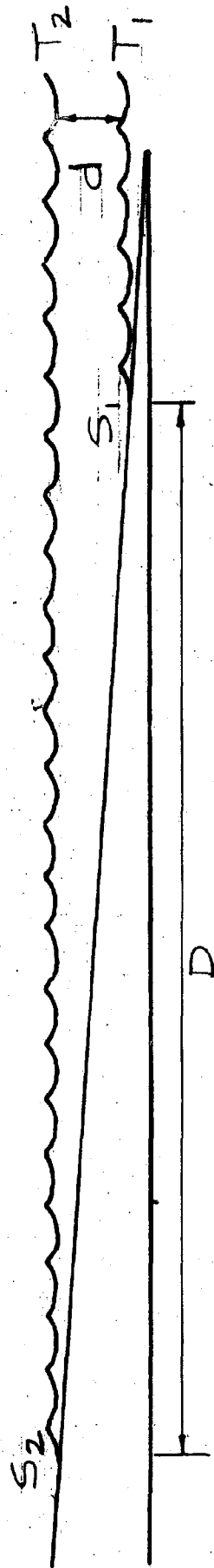
Coastal Processes and Shoreline Change

Though sea level rise is the underlying cause of shoreline recession, the work is performed by wind, waves and currents, particularly during storms. Several interacting coastal processes are involved which affect the ocean beach system. The beach, which consists of the storm berm, berm, swash zone and off-shore bar system (Figure 3) is an effective energy sponge. During normal day to day conditions, much of the energy of the waves is dissipated by the permeable slope of the swash zone as the wave wash moves up on and filters into the berm. A portion of the energy is also expended on moving sand both up and back down the face of the swash zone.

Since waves generally approach the coast at an angle, a current is produced which flows parallel with the shoreline. Sand is moved along the shoreline by the current as littoral drift. In North Carolina, this drift is predominantly from north to south and has been estimated to be as much as 370,000 cubic yards per year net near Oregon Inlet by the Army Corps of Engineers.

Energy levels increase during storms affecting dramatic changes on the beach system. High winds associated with storm conditions increase the wave height and decrease the wave length or distance between wave crests (Figure 4). This results in an increase in the wave energy which must be dissipated by the beach system. The larger and more closely spaced waves also increase the long shore

FIGURE 2.



T_1 = TIME BEFORE PRESENT

T_2 = TIME AT PRESENT

d = CHANGE IN SEA LEVEL FROM T_1 TO T_2

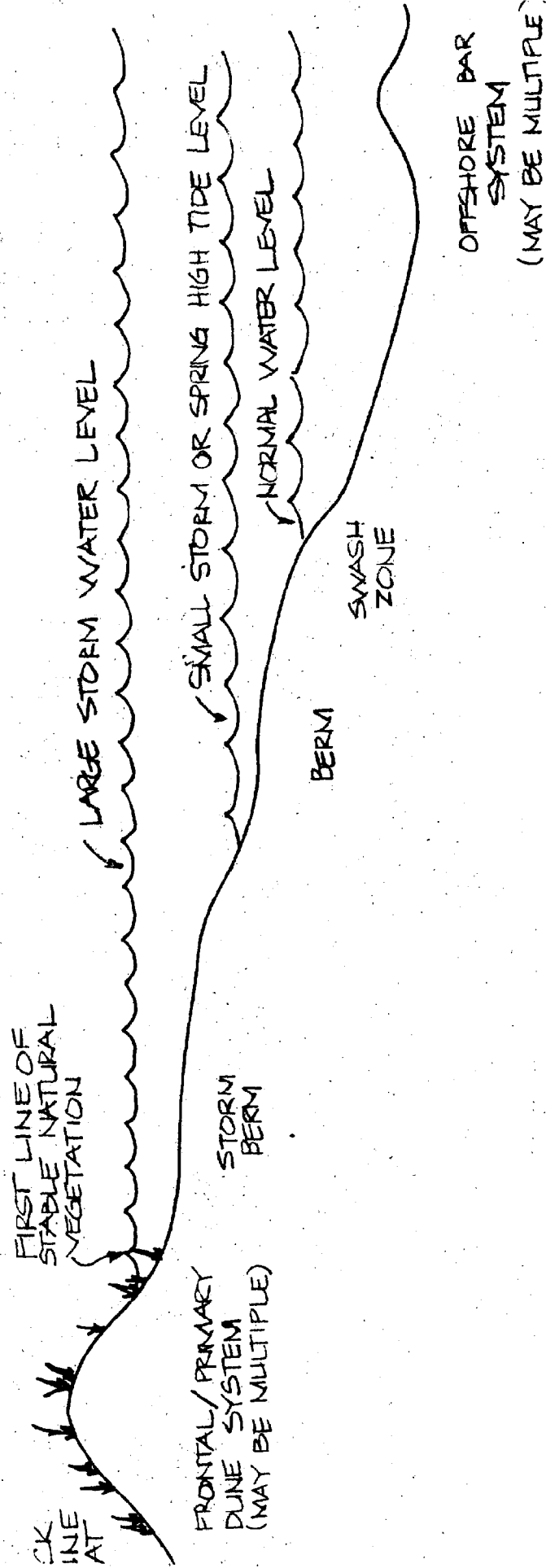
D = CHANGE IN SHORELINE FROM T_1 TO T_2

S_1 = LOCATION OF SHORELINE AT T_1

S_2 = LOCATION OF SHORELINE AT T_2

FIGURE 3.

COMPONENTS OF A TYPICAL BEACH ENERGY
DISSIPATION SYSTEM



current flow and its transport of littoral drift. In addition, low atmospheric pressures associated with storms cause a doming of water on the ocean surface called a storm surge. The increased elevation of the water surface moves the swash zone higher up the beach to the storm berm. During very large storms, the swash zone may move all the way up to the frontal dune (Figure 3).

During storms, sand held in storage on the beach is transported offshore and formed into one or more bars which help dissipate the energy of storm waves. This, in combination with the onshore shift of the swash zone produces a much broader and more effective energy dissipation zone (Figure 5). Generally, most of the sand moved offshore moves back onto the beach when normal energy conditions return.

Frontal dunes occur at a point landward of the beach where wave energy affects the barrier infrequently enough for pioneering vegetation such as American beach grass (*Ammophila breviligulata*) or sea oats (*Uniola paniculata*) to become established. These plants have developed special adaptations to salt spray and the wind blown (eolian) sedimentation processes dominating this portion of the environment. Once established, the grasses buffer wind energy causing sand blowing from the beach or inland to be dropped and accumulate in mounds around the plants. Burial stimulates growth of these frontal dune plant species so an upward growth of the mound of sand occurs. Dune grasses spread laterally relatively rapidly by sending out a system of rhizomes. As upward growth of the dune continues, new rhizomes are sent laterally just below the sediment surface. This produces a structural framework within the dune allowing it to maintain slopes considerably greater than the angle of repose for dry sand. This framework of rhizomes is commonly visible throughout the entire thickness of a dune truncated by large storm activity.

Generally, the frontal dunes continue to grow upwards as a series of hummocky mounds along the back side of the beach until they reach equilibrium with predominant wind energy conditions and sediment supply. During very large storms, some of the sand held in storage within frontal dunes is carried offshore and incorporated in the offshore bar system. Another portion of the sand is carried landward as overwash (adding elevation to the barrier). When the storm is over, the process of frontal dune development begins again, normally at a point somewhat landward of its original location.

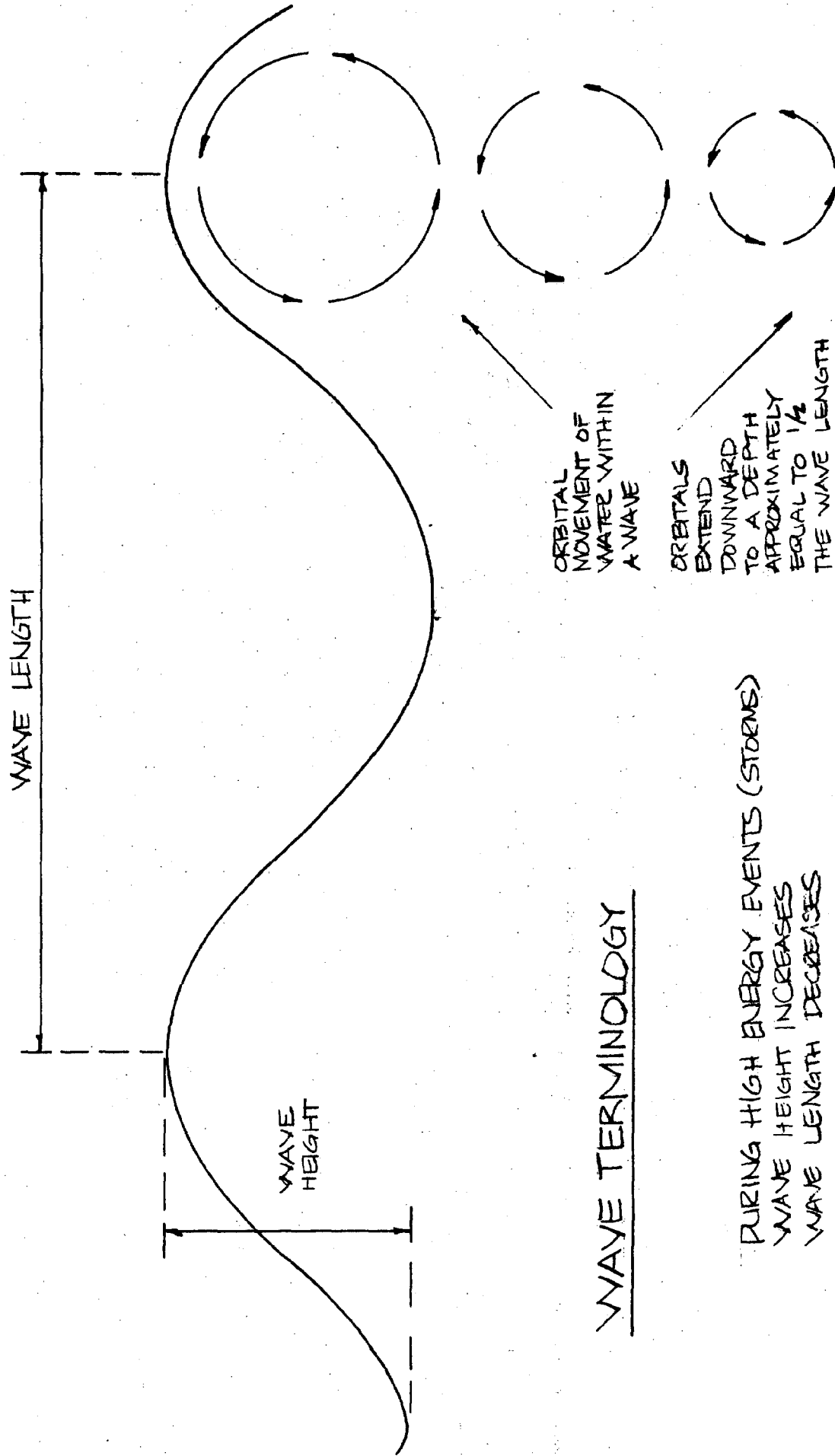
Sand carried offshore from the beach and frontal dune system during a large storm can result in a temporary shoreline retreat of as much as 500 feet. Thirty to 40 feet of temporary retreat is common during even relatively small storms. As this sand moves back onto the beach, generally within a year, most of this shoreline retreat is reversed. A large storm may only result in a net permanent loss of 10 feet.

Shoreline Recession and Long Term Barrier Island Processes

Over the past 15 years researchers have found that barrier islands can and do respond to rising sea level by migrating landward. This is accomplished primarily through inlet development, overwash and eolian processes. The role each plays varies somewhat from island to island and through time.

Volumetrically, inlets are the primary mechanism for moving sand from the ocean side to the back or estuarine side of barrier islands. Sediment budget studies indicate nearly 75% of the landward transport of sediment on North Carolina barrier islands is through inlets. Some of the sediment moving along the ocean beach (longshore transport) moves into the inlets through the inlet channels and is deposited on large shoals (flood tide deltas) which form on the

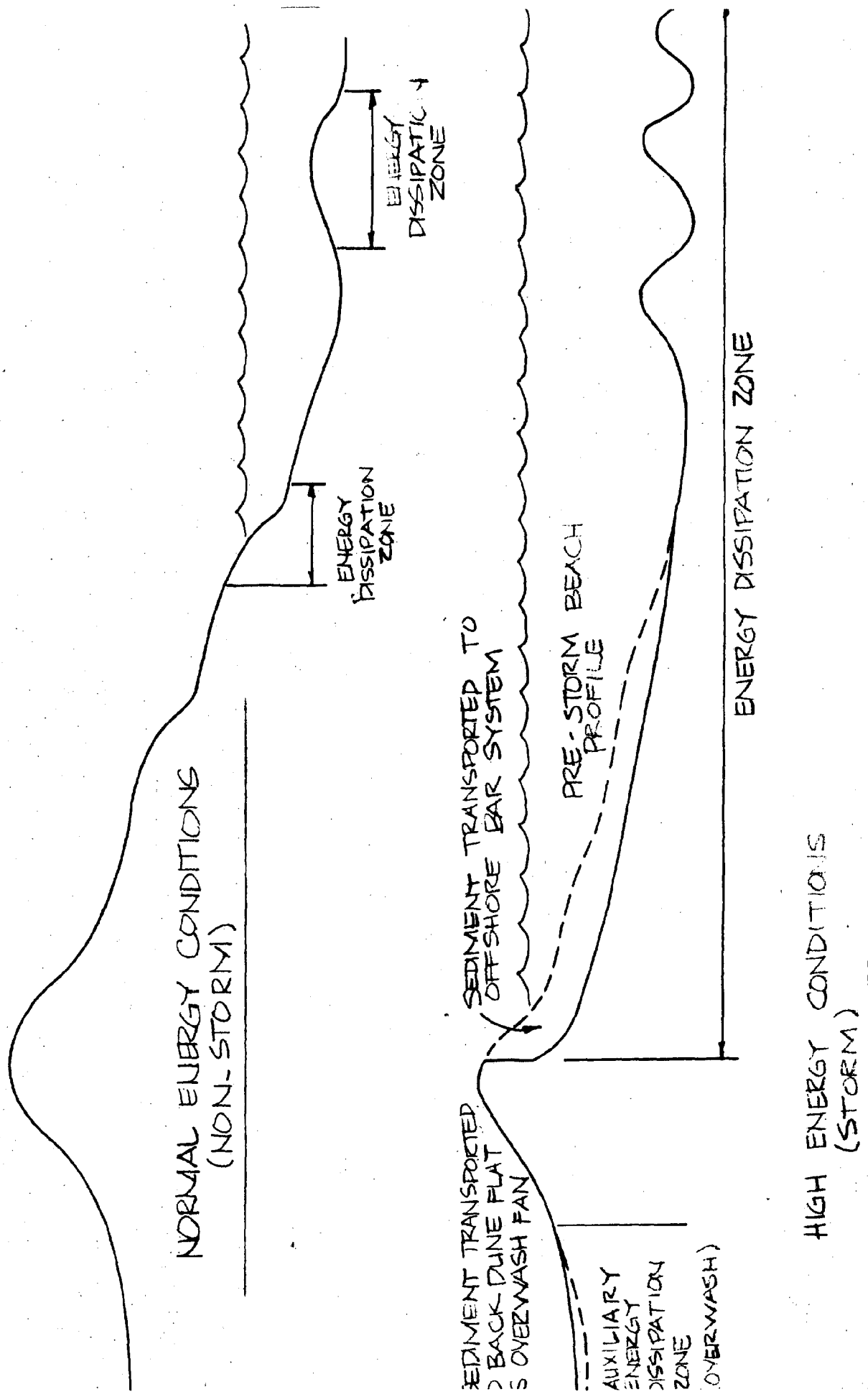
FIGURE 4.



WAVE TERMINOLOGY

DURING HIGH ENERGY EVENTS (STORMS)
WAVE HEIGHT INCREASES
WAVE LENGTH DECREASES

FIGURE 5.
 BEACH PROFILE AND SEDIMENT DISTRIBUTION
 RESPONSE TO CHANGING ENERGY CONDITIONS



estuarine side of barrier islands. As these inlet channels migrate (up and down the barrier islands within inlet migration zones in the southern half of the state or to the south in the northern half of the state), the actively building flood tide deltas also migrate producing broad platforms on the estuarine side along the inlet migration zone. This platform adds width to the island and provides a base on which the other island migration processes build.

Overwash and eolian processes add elevation to the backbone of barrier islands and provide a gradual landward shift in the island center of mass. These processes also provide a mechanism for the landward shift of all of the barrier island elements or zones which insures the continuation of energy equilibrium requirements. For example, the periodic landward shift of a frontal dune allows it to maintain the temporal stability period necessary for successful vegetation development as the beach narrows through shoreline erosion.

Barrier island migration is a relatively long term phenomena and not readily recognizable during one person's lifetime. Unlike many other geological processes, however, it has been significant within historic times. During the 300 years European man has lived on North Carolina's barrier islands, shoreline changes can be measured in thousands of feet, more than 20 inlets have opened, migrated and closed, another 20 or so are still open and migrating, and much of the present barrier island land has had an inlet passing through at one time or another.

Selected Bibliography

- Baker, E. J. (ed.), 1980, Hurricanes and coastal storms; Papers presented at a national conference: Florida Sea Grant College, Report No. 33, 219 p.
- Baker, S., 1978, Storms, people and property in coastal North Carolina: U.N.C. Sea Grant Publication. UNC-SG-78-15, 82 p.
- Bascom, W., 1964, Waves and beaches: The dynamics of the ocean surface: Anchor Books, Doubleday and Company, Inc. Garden City, NY, 267 p.
- Benton, S. B., 1979, Environmental assessment: Proposed ordinance clearance at the U.S. Army Corps of Engineers CERC Facility, Duck, North Carolina: North Carolina Department of Natural Resources and Community Development, Office of Coastal Management, Raleigh, N.C., 12 p.
- Clark, J. (ed.), 1976, Barrier islands and beaches: Technical Proceedings of the 1976 Barrier Islands Workshop, Annapolis, Maryland: The Conservation Foundation, Washington, D. C., 149 p.
- Cleary, W. J., and Hosier, P. E., 1977, New Hanover Banks: Then and now: U.N.C. Sea Grant Publication, number UNC-SG-77-14, Raleigh, N.C., 69 p.
- Collier, C.A., 1976, Bulkhead and revetment effectiveness, cost and construction, 2nd edition: Florida Department of Natural Resources
- Dolan, R., Hayden, B. P., and Heywpod, J. E., 1978, A new photogrammetric method for determining shoreline erosion: Coastal Engineering, v. 2, p. 21-39.
- Dolan, R., Hayden, B. P., May, P., and May, S., 1980, The reliability of shoreline change measurements from aerial photographs: Shore and Beach, v. 48, No. 4, p. 22- 29.
- Fisher, J. J., 1967, Development pattern of relict beach ridges, Outer Banks barrier chain, North Carolina: PhD. Dissertation, University of North Carolina, Chapel Hill, N. C. 250 p.
- Gares, P. A., Nordstrom, K. F. and Psuty, N. P., 1979, Coastal dunes: Their function, delineation, and management: Center for Coastal and Environmental Studies - Rutgers, New Brunswick, N. J., 112 p.
- Godfrey, P. J., and Godfrey, M. M., 1976, Barrier island ecology of Cape Look Lookout National Seashore and vicinity, North Carolina: National Park Service Monograph Series, Number 9, 160 p.
- Goldsmith, V. (ed.), 1977, Coastal processes and resulting forms of sediment accumulations, Currituck Spit, Virginia - North Carolina: Virginia Institute of Marine Science, Gloucester Point, VA., 46 p. plus contributions.
- Leatherman, S. P., (ed.), 1979, Barrier islands: From the Gulf of St. Lawrence to the Gulf of Mexico: Academic Press, New York, N. Y., 325 p.

- N. C. Council of Civil Defense, 1955, State of North Carolina long-range hurricane rehabilitation project: North Carolina Council of Civil Defense, Raleigh, N. C., 64 p.
- North Carolina Marine Science Council, 1981, Coastal study: Final report to the 1981 North Carolina General Assembly: North Carolina Department of Administration, Raleigh, NC, 83 p.
- Pilkey, O. H., Jr., Pilkey, O. H., Sr., and Turner, R., 1975, How to live with an island: A handbook to Bogue Banks, North Carolina: North Carolina Department of Natural and Economic Resources, Raleigh, N.C., 119p.
- Pilkey, O. H., Jr., Neal, W. J., Pilkey, O. H., Sr., Riggs, S. R., 1980, From Currituck to Calabash: Living with North Carolina's barrier islands: North Carolina Science and Technology Research Center, Research Triangle Park, N. C., 244 p.
- Ranwell, D. S., 1972, Ecology of salt marshes and sand dunes: John Wiley and Sons, Inc., New York, N. Y., 258 p.
- Riggs, S. R., and Benton, S. B., 1977, The northern Outer Banks of North Carolina: A layman's field trip guide through a dynamic barrier island system: Institute for Coastal and Marine Resources, East Carolina University, Greenville, N. C., 39 p.

